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Application of computational M&S for product development in Systems Engineering Framework

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Strengthening the System-Centric Approach

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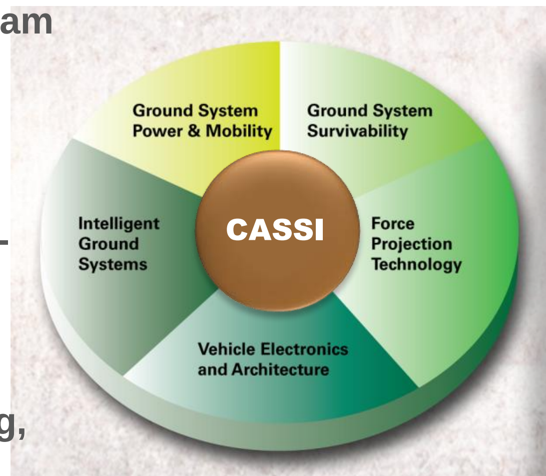
Concepts, Analysis, Systems, Simulations and Integrations (CASSI)

Coordinated approach to virtually describing, and testing new ideas and changes to existing systems.

- Requirements Capture, Concept Development, Program Formulation
- Physics-based Performance Assessments, Mathematical Modeling, Data Analysis
- Physical Validation, Systems-Level Validation
- Integrated System-Level Demonstrations
- High-Performance Computing, Product & Program Data Management



Supported Activities

- Gunners Restraint System
- MRAP Expedient Armor (MEAP)
- Support GCV Blue Ribbon Panel
- MRAP Size, Weight and Power (SWAP) Analysis for Tech Assessment
- Blast Modeling for Lightweight Underbody Protection System

CASSI Support to MRAP Expedient Armor Process

Characterize Vehicle Weight, Axle Loading, Center of Gravity, Suspension

Design Review and Performance Assessments

Final Fabrication

Physical Validation of Performance & Durability

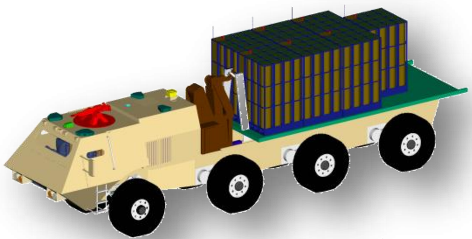
Re-Baseline

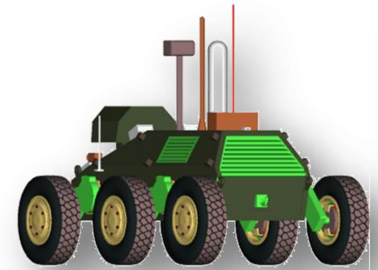
Endstate: Expedient Armor kit transitioned to depot for kit production

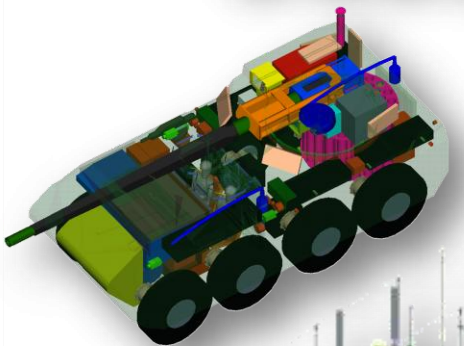
CASSI "C" - Concepts

Advanced Concepts Laboratory

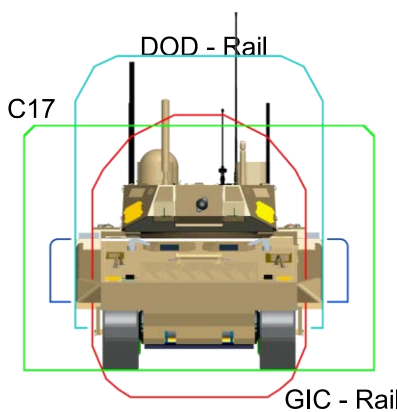
- Integrated Concepts Development
- 3D CAD System (Integration) Models
- SWAP Assessments
- Validated Requirements & Specs
- Support Trade Studies
- Technology Program Formulation
- Validated Technology Maturation Studies







JLTV CTV Concept



FCS ICV Transport vs. Armor Study

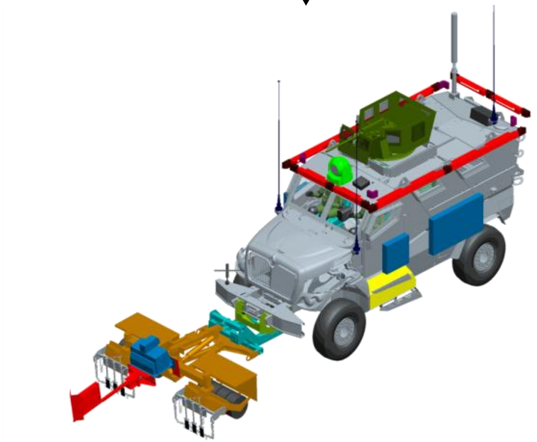
MRAP Caiman Technology Capability Insertion

Quantify Space and Weight Impacts and Feasibility

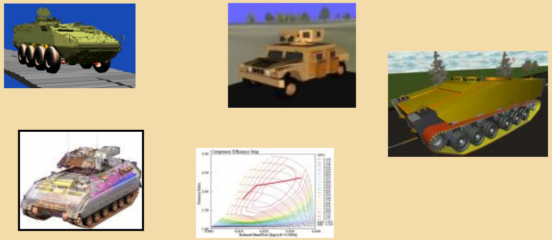
CASSI "A" - Analysis

System Level Analysis

MRAP Example



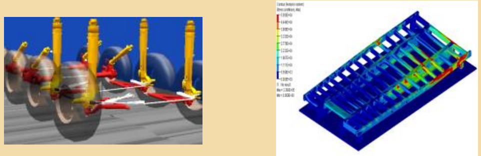
Mobility / Automotive Performance Analysis



Blast / Crash / Ballistic Analysis

Thermal / Signature / Aerodynamic Analysis

Durability / Reliability Analysis



High Performance Computing Infrastructure

System Level M&S Support Throughout Vehicle Lifecycle

<u>Acquisition</u>

- Generate CDD performance targets
- Help with concepts - trade-space sensitivity and SWAP-C studies and evaluation of proposed designs

<u>Current Force</u>

- Field System Support
  - Configuration changes
  - Safe Use Range of operation
- Evaluate Platform Modernization / Tech Insertion
  - HMMWV, FMTV, MRAP…..
  - Stryker, Bradley, Abrams….

<u>S&T</u>

- Evaluate technologies, vehicle concepts, tech-demonstrators
  - TWVS, CVAD, HEVEA, DCE, FED….





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Example – HMMWV M1114 Weight Growth Study SmartCard GTA & SOUM

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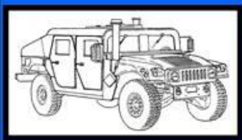
M1114 Payload Sensitivity Study



Payload Parameter Ranges

Baseline Values		Value Changes	
CGX	-130	-24, -12, 0, 12, 24	inches
CGY	0	-24, -12, 0, 12, 24	inches
CGZ	49.4	-24, -12, 0, 12, 24	inches
PAY Weight	1501.8	0, 1000, 2000	lbs
SPEED	0	40-60	MPH

Simulation Results

AVTP Double Lane Change (Worst Case X,Y)

PAYLOAD CG (in.)			PAY WEIGHT	SPEED	REDUCTION
CGX	CGY	CGZ	(lbs.)	(MPH)	(%)
-154	24	25.4	1502	50	0.0
-154	24	25.4	2502	50	0.0
-154	24	25.4	3502	49	2.0
-154	24	37.4	1502	49	2.0
-154	24	37.4	2502	48	4.0
-154	24	37.4	3502	47	6.0
-154	24	49.4	1502	48	4.0
-154	24	49.4	2502	47	6.0
-154	24	49.4	3502	45	10.0
-154	24	61.4	1502	46	8.0
-154	24	61.4	2502	45	10.0
-154	24	61.4	3502	43	14.0
-154	24	73.4	1502	45	10.0
-154	24	73.4	2502	44	12.0
-154	24	73.4	3502	41	18.0

NOTE: Payload CG measured: -X=distance behind front axle, +Y=distance left of vehicle center, +Z=distance above ground.

AVTP Shifted Payload Extreme Cases

	Min (MPH)	Max (MPH)	% Reduction
Forward Left	42	50	20.8
Forward Right	42	50	20.8
Rearward Left	41	49	22.6
Rearward Right	43	50	18.9

NOTE: Results for hard dry surface. Other conditions may further reduce speed for stable operation (tripping, side grades, soft shoulders, etc.)

M&S prediction of M1114 high-speed lateral stability at different payload weights and CG heights generated information for use in providing safety information to soldiers to avoid vehicle rollover

SMART CARD/GTA

WARNING: At Gross Vehicle Weight (GVW) rapid steering action at speeds as low as 40 MPH increases your likelihood of a Roll-over (GVW is an Unloaded M1114 plus 4 crew with basic gear). Road conditions such as sand, debris, gravel or rain will further reduce stability.

CONTRIBUTING FACTORS TO ROLL-OVER

*** Cargo placed high in vehicle *** Drivers Inexperience/Lack of Training ***
*** Overloading *** Road Conditions ***

ACTIONS TO REDUCE POTENTIAL ROLL-OVER

*** Conduct Driver's Training *** Stay Within Recommended Payloads ***
*** Place and Secure Cargo as low as possible in the vehicle ***
*** Reduce Speed when Anticipating a Rapid Maneuver ***
*** Maintain Tire Pressures of 40 psi front / 50 psi rear ***

** GVW is an Unloaded M1114 plus 4 crew with basic gear **

Stopping Distance at 60 MPH

GVW	13 Vehicle Lengths
GVW+2000 lbs.	15 Vehicle Lengths

WARNING: At 60 MPH on smooth dry pavement an overloaded M1114 has a braking distance of 15 vehicle lengths, compared to 13 vehicle lengths at GVW. Road conditions such as sand, debris, gravel or rain will further increase stopping distances.

CAUTION: This information is provided so that commanders can manage risk when vehicles are overloaded, or cargo is placed high in the vehicle, or traveling at speeds in excess of 40 mph. Authorized GVW is 12,100 pounds.

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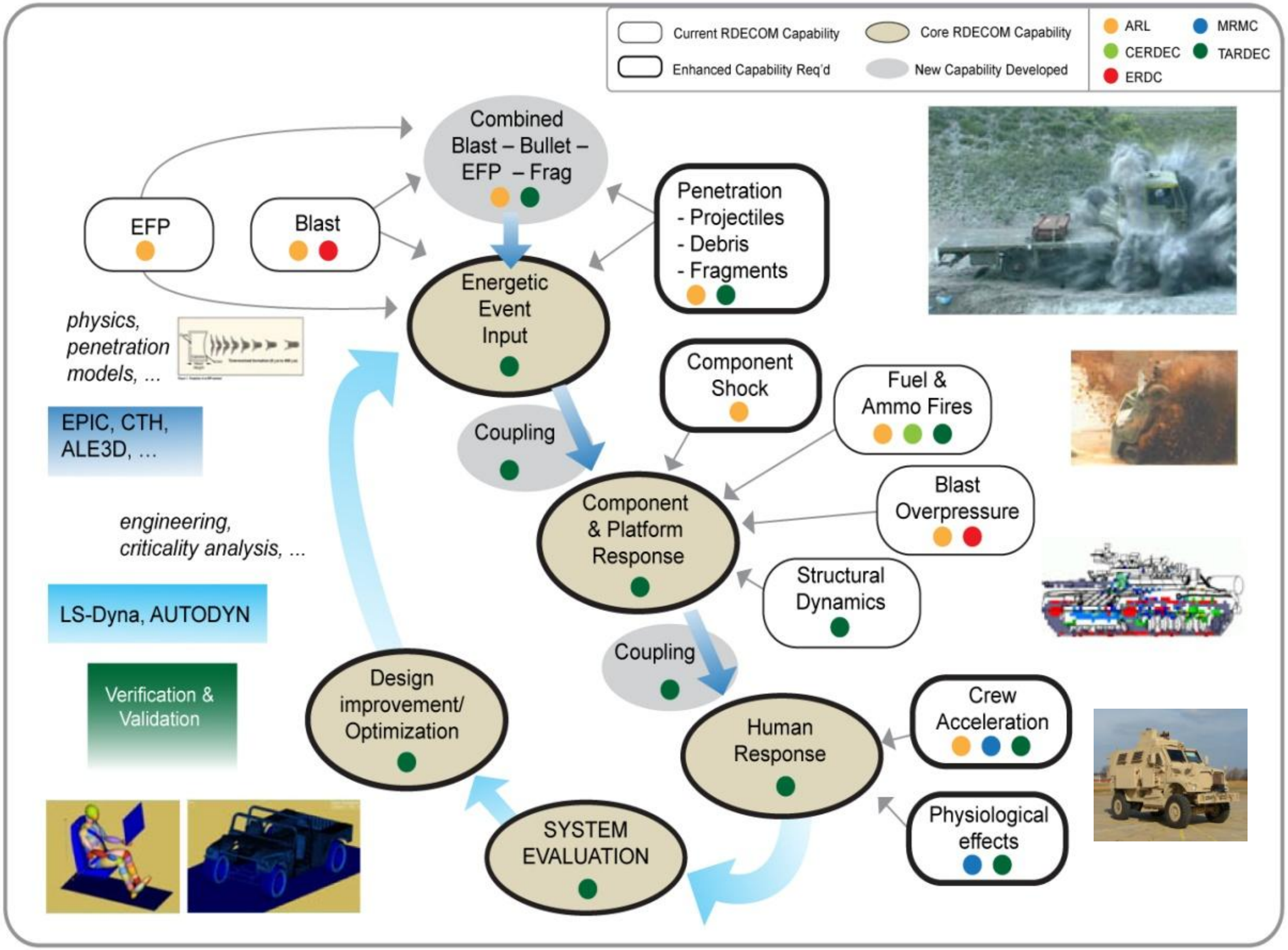
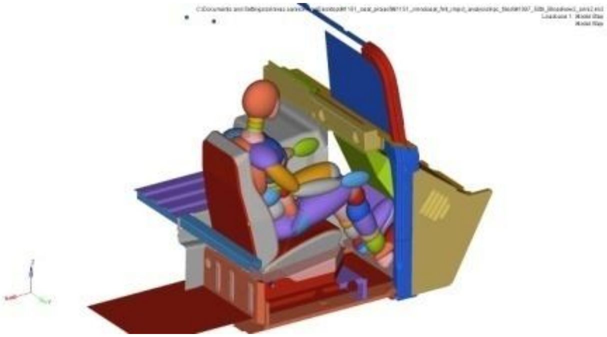
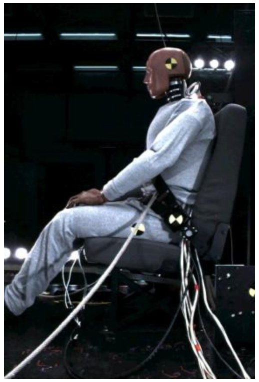
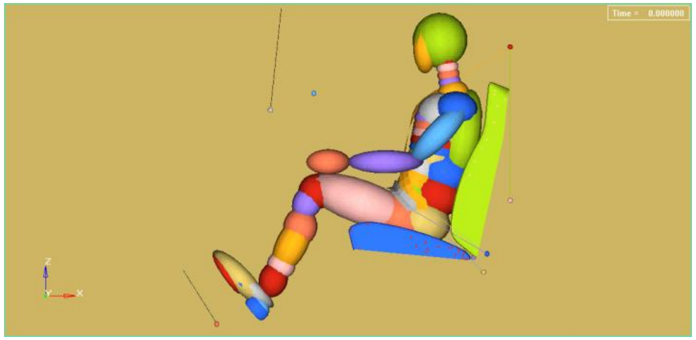
Underbody Blast Modeling

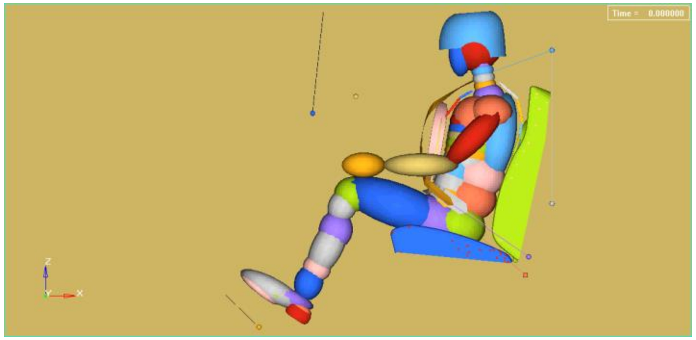


Crashworthiness Modeling









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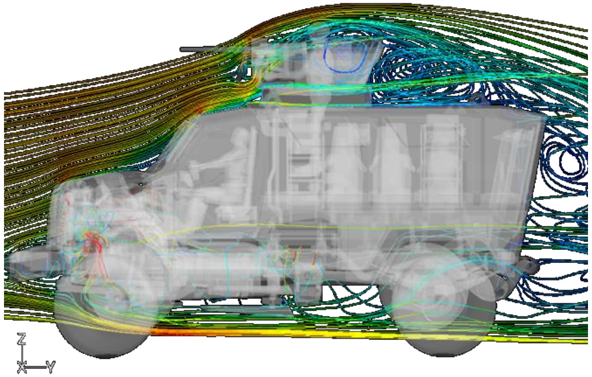
Thermal & Signature Modeling

Computational Fluids (CFD)

- Thermal budgeting/ efficiency analysis
- HVAC design / interior cooling
- Underhood cooling
- Fire suppression modeling
- Pressure drops of ballistic grilles

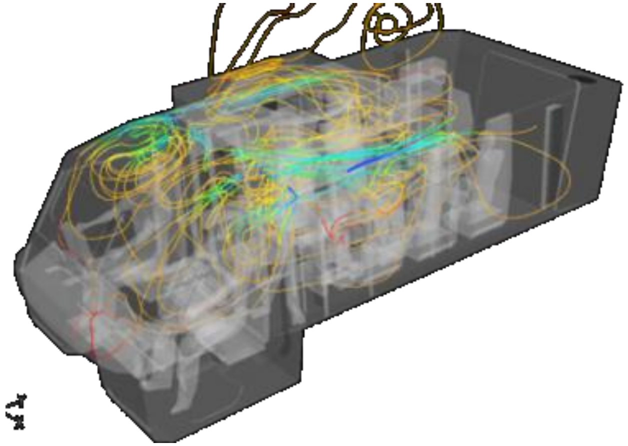
Signatures

- Visual, IR, radar, acoustics



External & Underhood

20 MPH w/ Hatch Open



Interior: All Components & Crew

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Vehicle Thermal Modeling

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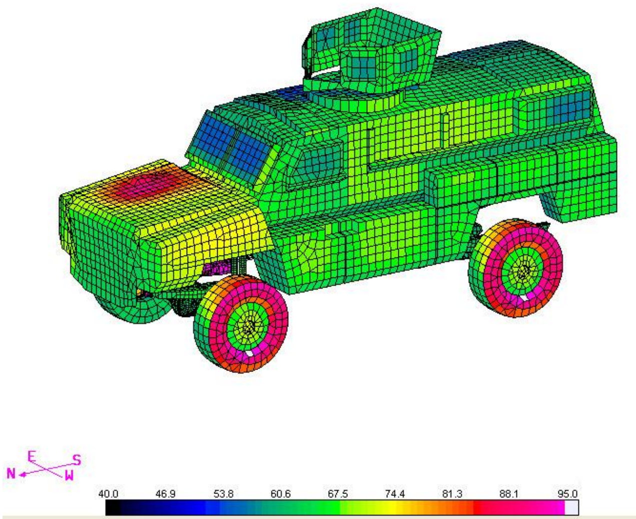
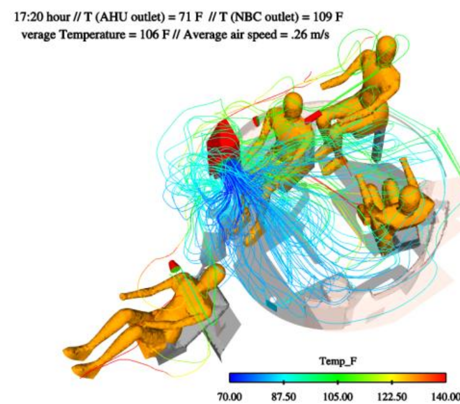
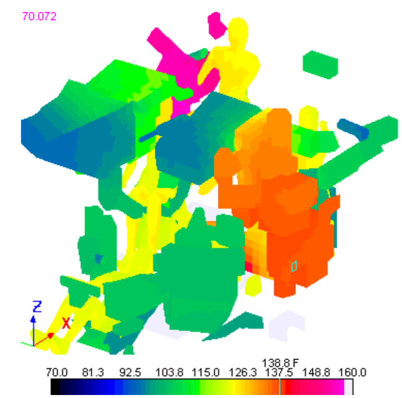
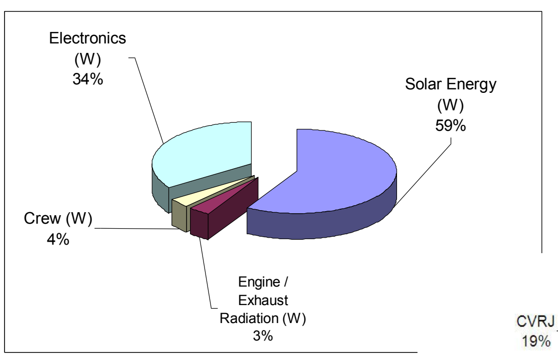
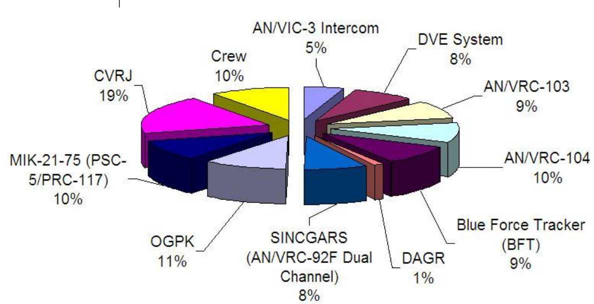






Description	Thermal Sensation
Hot	**+3**
Warm	**+2**
Slightly Warm	**+1**
Neutral	**0**
Slightly Cool	**-1**
Cool	**-2**
Cold	**-3**





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Example: Caiman C2OTM HVAC

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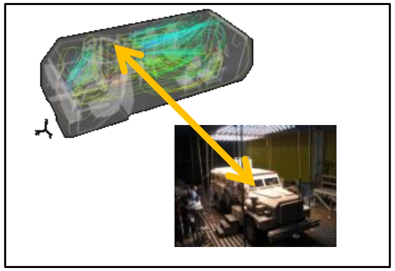
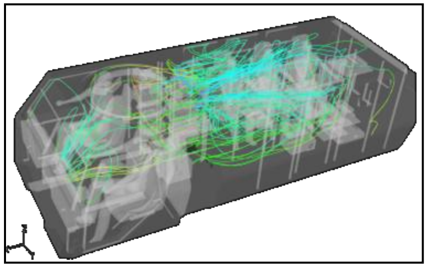
Modeling

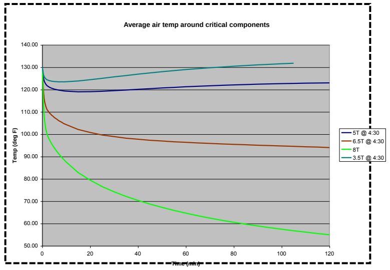


Model Validation



Validated C2OTM Baseline (idle)

New Duct Design / Optimization



Cooldown HVAC Capacity Study

Cooldown equip in 15 minutes

Physical Simulation – Cell 9

- Surrogate racks / equip
- PVC human “dummies”

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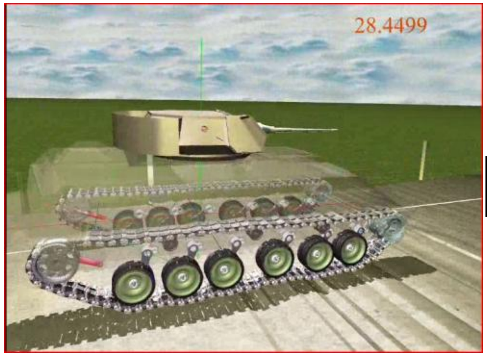
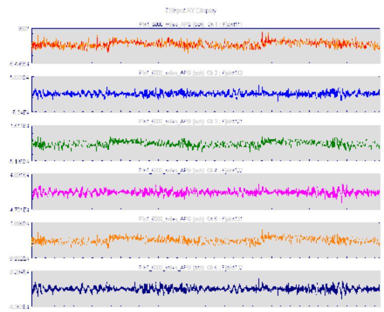
Reliability Modeling Example

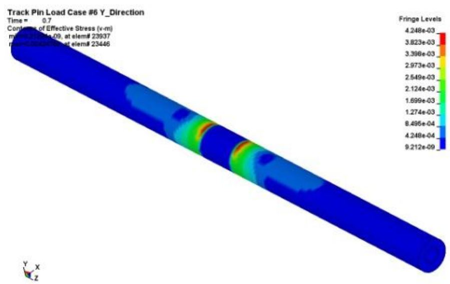


Multi-body dynamic simulation software used to generate duty cycle loading information for the track pin.

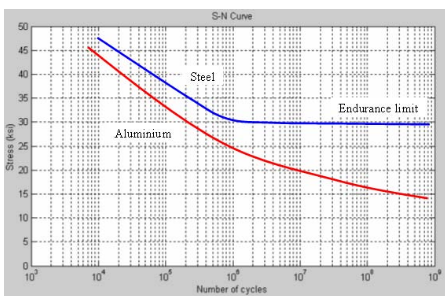
- Dynamic Analysis Design System (DADS)
- Integrated Virtual Reality Environment for Synthesis and Simulation (IVRESS)



Duty cycle loads

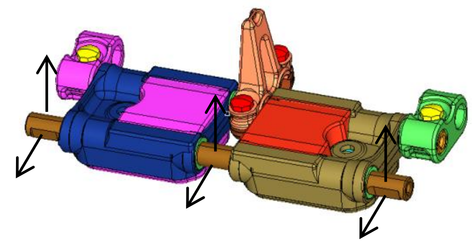


FEA model

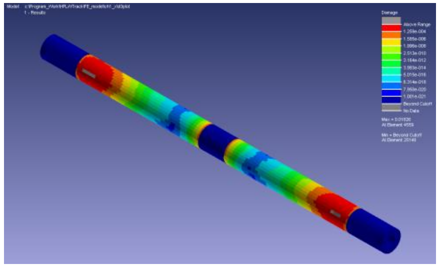


Material Characteristics

Ncode DesignLife Fatigue Analysis Software



Fatigue Life Prediction



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Multi-Disciplinary Optimization

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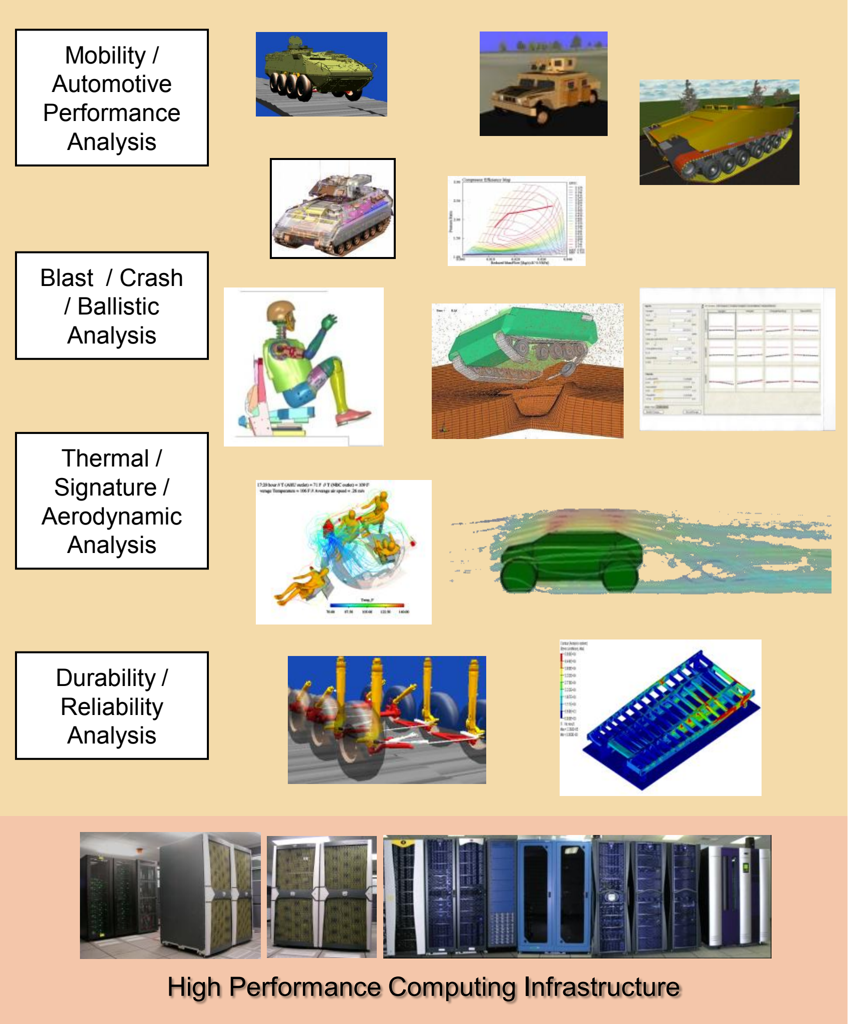
Multi-disciplinary optimization (MDO) is a design approach for meeting multiple discipline-level targets while also achieving top level objectives and satisfying all design constraints.



Inputs:

- Top-level design objectives and constraints
- Discipline-level design objectives and constraints
- Model of initial design
- Sufficient data to support M&S for each discipline

Outputs:

- New design that is optimized to best meet system-level and discipline-level objectives while satisfying all constraints

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CASSI "SS" – System Simulation

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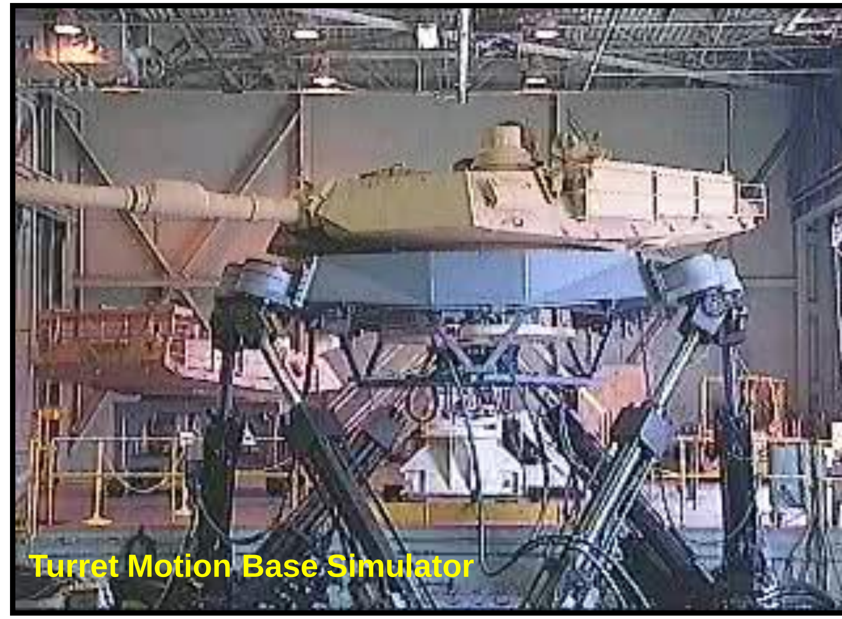

Ground Vehicle Simulation Laboratory

- Vehicle Characterization
- System Durability Studies
- Performance Validation
- System "Shakedown" Testing
- Man-In-the-Loop Testing

Computing & Data Management

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S&T - ATO

Requirements

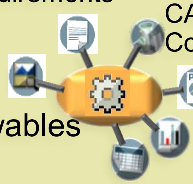
CAD Model / Configurations

Viewables

Data Sheets

Analysis / Simulation

Test Plan/Data



Assessment Summaries

S&T – Tech / Pgm Data Management
Technology Assessments

High Performance Computing Systems

Network Backbone

MRAP – Deployment / Sustainment

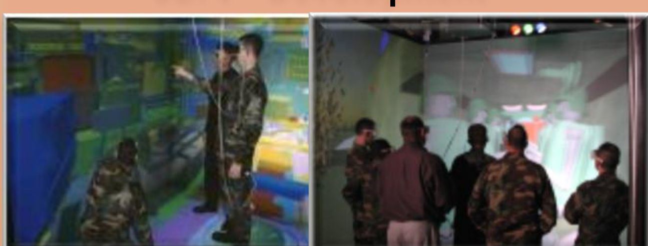
Configuration Management
CDRL Delivery, Field Issues Management

A — B (Program Initiation) — C — IOC — FOC

Materiel Solution Analysis	Technology Development	Engineering and Manufacturing Development	Production & Deployment	Operations & Support
Materiel Development Decision		Post-PDR A, Post-CDR A	LRIP/IOT&E, FRP Decision Review	

Pre-Systems Acquisition | Systems Acquisition | Sustainment

JLTV - Development



Requirements Traceability Management
CAVE – Virtual Design Reviews

System / Platform Data

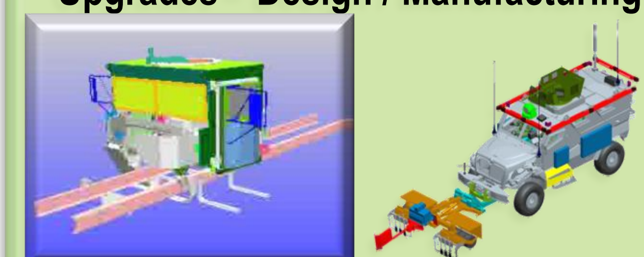
Technology Data

Program Data

Collaborative Processes

Integrated Data Management

Upgrades – Design / Manufacturing



Product (Technical) Data Management
Mark-up and Eng Change Management

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Systems Demonstrators Role in Technology Readiness Level

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Technology Readiness Level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Systems Demonstrators generally will provide the ability for technologies to transition to Readiness Level 6, but may include Operational Environment demonstrations at TRL 7

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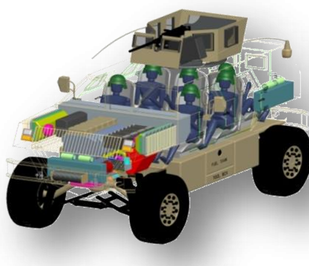
Summary

- Concepts, Analysis, System Simulation and Integration (CASSI) capabilities are critical services enabling both Technology Development and System Development Programs.
- With consolidation and improved efficiency, TARDEC is positioning its CASSI services to be a key enabler for Army Programs.
  - Consistent use across Technology and System Programs
  - Single Interface for all Customers
  - Expanded focus on System-of-Systems Perspective
  - Improved Information Management and Sharing
  - Expanded Means for Partner and Customer Collaboration



- CASSI is central to achieving TARDEC's role as the Army's Ground Systems Integration Domain Lead.
- Computational modeling and simulation plays a pivotal role in the evaluation of expanded design space to improve product quality and performance and reduce product development costs.
- Current advances in High Performance Computing infrastructure and computational software provide path forward for Multi-Disciplinary Optimization (MDO) for balancing diverse requirements and objectives for various functional areas.

Requirements + Technology + Assessment + Integration
»»» Improved Alignment and Transition